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ALLEGHENY RIVER RESERVOIR

BENEFITS RESULTING FROM LOW-FLOW REGULATION BY THE PROPOSED ALLEGHENY RESERVOIR

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Benefits Resulting from Low-Flow Regulation by the Proposed Allegheny Reservoir

1. Allegheny River Basin
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see
Allegheny River

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INTRODUCTION

In November, 1956 the District Engineer, Pittsburgh District, Corps of Engineers, U. S. Army requested the Public Health Service to prepare an evaluation of benefits that would result from low-flow regulation by the proposed Allegheny Reservoir. The Public Health Service was specifically requested to "...make such studies as necessary to evaluate pollution abatement and water supply benefits that would result from operation of the Allegheny Reservoir for the dual purposes of flood control and low-flow regulation; and further, to evaluate the similar benefits that would result incidentally from substitution of hydroelectric power for the collateral low-flow regulation function."

Benefits attributable to low-flow regulation from the Allegheny Reservoir have been estimated previously in the following reports:

1. Allegheny River, N. Y. and Pa. - Allegheny Reservoir, H. D. No. 300, 76th Congress, 1st Session (1939)
2. Ohio River Pollution Control, Report of the United States Public Health Service, House Document No. 266, 78th Congress, 1st Session (1944)
3. Allegheny and Monongahela Rivers and Tributaries, House Document No. 491, 83rd Congress, 2nd Session (1954)

The most recent estimates of benefits were prepared by the Public Health Service in a memorandum report which was included as an appendix to House Document No. 491 (reference No. 3 above). Benefits estimated in the above report were obtained in large part by adjustment of those presented in

House Document No. 266 (reference No. 2 above), which represented conditions as of about 1940. Many of the basic factors relating to damages resulting from adverse water quality, and benefits resulting from the improvement of water quality have changed significantly since the basic data for House Document No. 266 were obtained. One very important change involves the advent of household detergents, which significantly affects the determination of benefits resulting from hardness reduction. Such benefits were previously based on soap savings. Other changes affecting the determination of benefits include changes in municipal and industrial water use, changes in the treatment of this water, changes in waste treatment, and changes in navigation facilities. In addition, other reservoirs with low-flow regulation features have been completed in the Allegheny and Monongahela basins and their effects must be recognized. These considerations indicate the desirability of a rather complete re-examination of the situation in order that the estimated benefits resulting from low-flow regulation by the Allegheny Reservoir best represent current conditions.

SUMMARY AND CONCLUSIONS

1. The waters of the Allegheny and upper Ohio Rivers are used extensively for municipal and industrial water supply. Municipal water supplies take an average of 155.90 million gallons of water daily from the Allegheny River below its confluence with the Clarion River. Of this total, 153.78 MGD is taken from the Allegheny River in the 30-mile reach below its confluence with the Kiskiminetas River. There are two public water supplies, using an average of 2.73 million gallons of water daily, on the Ohio River in the State of Pennsylvania.(1)

2. Industrial water supplies were reported, (2) in 1951, to use an average of 2800 million gallons of surface water daily from private supplies on the Allegheny, Monongahela and Ohio Rivers in the Pittsburgh area. More than 57% of this water was used for cooling in steam power generation and more than 41% was used in the manufacture of iron, steel and allied products. Industries contacted in 1957 by the Public Health Service indicated that the major use of surface waters in industrial processes occurs on the Upper Ohio River where about 90 MGD is used for this purpose.

3. Both the Allegheny and Ohio Rivers have been extensively developed for navigation. Eight locks and dams on the Allegheny River provide

(1) Reported by Pennsylvania Department of Health, Division of Sanitary Engineering, Region III and Region IV.
The Municipal Authority of the Borough of Midland, Water Dept. (2.5 MGD)
The Dixmont State Hospital, Kilbuck Twp. (0.23 MGD)

(2) U. S. Geological Survey Circular No. 315, "Water Resources of the Pittsburgh Area, Pennsylvania."

slack water navigation from Pittsburgh, Pa. to above East Brady, Pa., a distance of 72 miles. The Ohio River is developed for navigation throughout its length. Commercial barge traffic on the Ohio River at Emsworth Lock and Dam, 6 miles below the confluence of the Allegheny and Monongahela Rivers, has been reported by the Pittsburgh District, Corps of Engineers, U. S. Army, to average 880 tows per month with an average of 6 barges per tow. On the Allegheny River at Lock and Dam 2 the traffic was reported to average 260 tows per month with an average of 3 barges per tow.

4. In addition to the above uses, the Allegheny and Ohio Rivers serve as the receiving waters for wastes discharged from municipalities and industries located along their banks. At the present time the State of Pennsylvania requires that all wastes receive a minimum of primary sewage treatment, or equivalent, before being discharged to either the Ohio or Allegheny Rivers.

5. The Kiskiminetas River is the chief source of mineral pollution in the lower Allegheny River. The water has a high acid content, due mostly to acid mine drainage, and is the main cause of corrosion problems in the lower Allegheny River. The Kiskiminetas also contributes considerable hardness to the main stream and is the chief source of manganese problems in downstream water supplies.

6. The principal public water supply problems in the lower Allegheny River are associated with the occurrence of acidity and manganese in raw water supplies. Low-flow augmentation from the Allegheny Reservoir will materially reduce the concentrations of these

constituents during critical low-flow periods, resulting in a reduction in treatment costs. Practically none of the water produced by public water supplies on the lower Allegheny River is softened. Low-flow augmentation will, however, result in hardness reductions with coincident benefits to water consumers.

7. The principal problems involving the quality of industrial water supplies on the lower Allegheny and upper Ohio Rivers are associated with the occurrence of hardness and acidity. Low-flow augmentation from the Allegheny Reservoir will materially reduce the concentrations of these constituents during critical low-flow periods, resulting in direct benefits to industrial water users. In addition, low-flow augmentation will result in a decrease in river water temperatures which will be reflected in an increase in the efficiency of industrial cooling systems using river water.

8. The corrosive action of acid waters in the lower Allegheny and upper Ohio Rivers is of considerable concern to navigation interests. Corrosive conditions result in damage to floating navigation plant (barges and tow boats) and to the submerged portions of fixed structures such as locks and dams, harbor facilities, and bridges. Low-flow augmentation will materially reduce acid concentrations during critical low-flow periods with a resulting decrease in corrosion damage to navigation interests.

9. The greatest pollution abatement problem affected by low-flow augmentation from the Allegheny Reservoir is in the Pittsburgh area.

The Allegheny County Sanitary Authority has under construction a sewage treatment plant near McKees Rocks on the Ohio River. This plant will provide primary treatment with pre-aeration and chlorination for most of the wastes from the City of Pittsburgh and 68 other municipalities in surrounding areas. Based upon low-flow frequency studies and loads estimated for the year 1965 by the Allegheny County Sanitary Authority it has been estimated that, unless low-flow augmentation is provided from the Allegheny Reservoir, complete treatment will be required at Pittsburgh to maintain desirable dissolved oxygen objectives in the upper Ohio River as recommended by the Ohio River Valley Water Sanitation Commission. If low-flow augmentation is provided from the Allegheny Reservoir a lesser degree of treatment, probably chemical precipitation, should be sufficient. This will mean considerable savings in annual operation expense and amortized capital cost. In addition to the Pittsburgh area, it has been estimated that a saving in chemical costs for sewage treatment at Cincinnati, Ohio may be attributed to low-flow augmentation from the Allegheny Reservoir.

10. Average annual tangible benefits attributable to low-flow augmentation from the Allegheny Reservoir have been estimated and are presented in the following table:

SUMMARY OF AVERAGE ANNUAL
TANGIBLE BENEFITS

Public Water Supplies			
Manganese Reduction		$ 37,000	
Hardness Reduction		176,000	
Acidity Reduction		7,000	
	TOTAL		$221,000
Industrial Water Supplies			
Hardness Reduction		$ 77,000	
Temperature Reduction (cooling water)		98,000	
	TOTAL		$175,000
Navigation (corrosion reduction)			$20,000
Pollution Abatement			$730,000
Total			$1,146,000

11. Many of the beneficial effects of low-flow regulation are not capable of economic evaluation and must be considered intangible. General improvements in water quality downstream from sources of pollution may result from low-flow augmentation even though required degrees of waste treatment are not reduced. Low-flow augmentation will also result in increased dilution of aesthetically objectionable waste characteristics, such as color, which are difficult or impractical to remove by conventional treatment methods. The ultimate value of these improvements will be reflected in an increased ability of the Allegheny and Ohio Rivers to assimilate the additional wastes resulting from future population growth and industrial expansion.

Intangible benefits to public water supplies will result primarily from the maintenance of more uniform raw water quality. This will simplify treatment procedures and lessen the chance of widely fluctuating raw water quality upsetting treatment processes. In this respect, low-flow augmentation may be considered to have a general public health benefit in that it helps to mitigate a potential health menace which would result if treatment processes were disrupted. Augmentation will also help to mitigate taste and odor problems which occur in water supplies on the Allegheny River.

The major intangible benefit to industrial water supplies will result from the maintenance of a more uniform raw water quality. In addition to simplifying treatment procedures, this will be of particular value to those industries where uniform process water quality is critical.

Low-flow augmentation will materially enhance the value of the Allegheny River for recreational uses. This effect will be felt throughout the length of the River but should be most important in the Pittsburgh area and in the immediate vicinity of the reservoir.

One of the most important factors in industrial location is the assurance of an adequate supply of high quality water. Improvements in water quality and increased discharges during low-flow periods should make the entire Allegheny River more attractive for industrial development.

12. One of the greatest potential hazards to water users in the lower Allegheny River is the possible occurrence of slug discharges from the Kiskiminetas River. These discharges are of objectionable quality and represent a menace to downstream treatment plants. The junction of the Kiskiminetas River with the Allegheny River is approximately 170 miles below the site of the proposed Allegheny Reservoir Dam. It is doubtful whether scheduled reservoir releases would be effective in mitigating the effect of slug discharges from the Kiskiminetas River. It has been previously recommended (1) that pondage be developed on pool No. 5, Allegheny River, to provide storage that would be immediately available for dilution of unusual discharges from the Kiskiminetas River. It has also been recommended (1) that a low barrier be constructed which would project from the left bank of the Kiskiminetas River out into the Allegheny

(1) Allegheny River, N.Y. and Pa. - Allegheny Reservoir, H.D. No. 300, 76th Congress, 1st Session (1939).

River in order to insure mixing of Kiskiminetas River discharges in the Allegheny River. These facilities would greatly increase the effectiveness of low-flow regulation from the proposed Allegheny Reservoir and it is recommended that they be included in the reservoir project as supplemental works.

SCOPE AND LIMITATIONS

Benefits may, in general, be classified as either tangible or intangible. Tangible benefits are those which are capable of economic evaluation. These benefits are usually determined in terms of the most economical alternative method of obtaining the same result and are expressed as an annual charge in dollars. Intangible benefits are those benefits not capable of economic evaluation, such as recreation, public health and aesthetic improvements.

The only reservoir in the Allegheny River Basin providing low-flow augmentation at the present time is the East Branch Reservoir on the Clarion River. It is stated in House Document No. 491 that this reservoir will provide an increase in low-flow of 190 cfs as compared to an increase of 2005 cfs from the Allegheny Reservoir. There are two reservoirs in the Monongahela River Basin providing low-flow augmentation at the present time. The Tygart River Reservoir provides an increase in low-flow of 327 cfs and the Youghiogheny River Reservoir provides 700 cfs. These increases in low-flow are those that would have been available in the driest summer month in the normal 10-year period preceding 1948. The effects of these low-flow increases have been recognized in evaluating benefits expected to result from low-flow augmentation by the Allegheny Reservoir.

The major water quality problems on the Allegheny River occur in that portion of the river below the Kiskiminetas River. Benefits to municipal and industrial water supplies and navigation resulting

from improved water quality due to low-flow augmentation are limited in this report to the Upper Ohio River and the Allegheny River below the Kiskiminetas River.

Benefits to pollution abatement resulting from low-flow augmentation will occur throughout the Allegheny and Ohio Rivers insofar as increased discharge during low-flow periods will improve conditions below all sources of pollution. Tangible monetary benefits to pollution abatement estimated in this report are restricted to the Pittsburgh area with incidental benefits at Cincinnati resulting from an anticipated reduction in chemical usage. A large industrial development has been proposed for the Allegheny River near Franklin, Pennsylvania. Should this development be realized, material benefits should result from the proposed low-flow augmentation.

The Public Health Service was requested to evaluate benefits that would result incidentally from substitution of hydroelectric power for the collateral low-flow regulation function of the reservoir. Since data relative to the operation of the reservoir for power generation were not available at the time this report was prepared, this condition has not been specifically evaluated.

ACKNOWLEDGMENTS

The cooperation and assistance furnished by both governmental agencies and industry is gratefully acknowledged. The Pennsylvania Health Department Regional Office at Meadville provided data relative to water use and pollution loads. The Pittsburgh Regional Office of the Pennsylvania Health Department provided similar data and in addition made arrangements for securing detailed information from water plants, industry, and other sources. Water plant and industrial personnel were very cooperative in making requested data available. The Allegheny County Sanitary Authority furnished much valuable information regarding their sewage treatment plant and also made data available from several stream surveys. The U. S. Geological Survey made unpublished water quality and stream flow data available. Additional data were taken from U.S.G.S. published records. Simulated flow conditions from the proposed reservoir were provided by the Pittsburgh District Office, Corps of Engineers, U. S. Army.

RESERVOIR OPERATION

"Allegheny River Reservoir is one of the reservoirs in the Ohio River Basin above Pittsburgh authorized by the Flood Control Act of 1936 as modified by the Flood Control Act of June 28, 1938 and subsequent acts, as a comprehensive plan for the protection of Pittsburgh and for the reduction of flood heights in the Ohio Valley. The reservoir will be located in Warren and McKean Counties, Pennsylvania, and Cattaraugus County, New York, with the dam site approximately 200 miles above the junction of the Allegheny River with the Monongahela River. The proposed reservoir, which controls a drainage area of about 2180 square miles, would have a total storage capacity of about 1,125,000 acre feet at an elevation of 1365 feet above mean sea level, or about 165 feet above the existing stream bed. At elevation 1365 the reservoir area would be approximately 21,000 acres. The present plan calls for a dual purpose reservoir for flood control and low water regulation. During the winter, the storage above elevation 1291 would be allocated for flood control whereas the storage above elevation 1328 would be allocated for that purpose in the summer period. The storage above elevations 1291 and 1328 amount to 905,000 acre feet and 585,000 acre feet, or 7.8 and 5.0 inches of runoff, respectively."(1)

Principal features of the proposed reservoir, upon which this report is based, are shown in Tables 1 and 2 and Figure 1.

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(1) Allegheny River Reservoir, Allegheny River Basin, Design Memorandum 1, Hydrology, Pittsburgh District, Corps of Engineers, U. S. Army, Pittsburgh, Pa., August 1956.

Table 1

ALLEGHENY RESERVOIR

Storage Allocations

Allocation	Storage (Acre-feet)	
	Summer	Winter
Dead Storage	20,000	20,000
Flood Control (Minimum)	585,000	905,000
Low Flow Regulation (Maximum)	520,000	200,000
Gross Storage	1,125,000	1,125,000

Table 2

ALLEGHENY RESERVOIR

Pool Elevations

Pool	Elevation (Feet above MSL)
Permanent (Dead Storage)	1240.0
Summer	1328.0
Winter	1291.0
Reservoir Full	1365.0

The basis of low-flow augmentation releases is shown in Figure 1. It may be seen that these releases are based upon maintaining a minimum flow at Lock 4, Allegheny River, which is 24.2 miles above the confluence of the Allegheny and Monongahela Rivers at Pittsburgh. The minimum continuous flow to be maintained will vary from 2000 cfs when storage is in Zone A to 5000 cfs when storage is in Zone F (maximum low-flow regulation storage).

DETERMINATION OF TANGIBLE BENEFITS

Pollution Abatement

Benefits to pollution abatement attributable to low-flow augmentation are considered to occur only if the augmentation makes possible a reduction in the required degree of waste treatment. Plain sedimentation (primary sewage treatment) is considered to be a minimum requirement and benefits are allocated only insofar as treatment requirements in excess of primary treatment are reduced or eliminated by low-flow augmentation.

At the present time a minimum of primary treatment is required by the State of Pennsylvania for all major sources of municipal wastes discharged to the Allegheny River below the site of the proposed Allegheny Reservoir. Unless these requirements are increased, no pollution abatement benefits will result from low-flow augmentation. A possible exception may occur in the vicinity of Franklin and Oil City, Pennsylvania. If the proposed industrial development on the Allegheny River near Franklin is realized, it is possible that both Franklin and Oil City might be required to achieve a higher degree of treatment than now required. Such a requirement would be imposed under existing flow conditions if the total load discharged to the river is increased sufficiently to cause degredation of river water quality below desirable standards. The Allegheny Reservoir would provide a considerable increase in low-flow in the Franklin area. Figure 5 shows a frequency analysis of seven-day mean low-flows on the Allegheny River at Franklin. The Allegheny Reservoir will increase the seven-day mean low-flow occurring once in ten years from 480 cfs to 2600 cfs. This increase should be sufficient to reduce or possibly

eliminate additional treatment requirements should the proposed industrial development be realized at Franklin.

The greatest benefit to pollution abatement will occur in the Pittsburgh area. The Allegheny County Sanitary Authority has under construction a sewage treatment plant near McKees Rocks on the Ohio River. This plant will treat most of the wastes from the City of Pittsburgh and 69 other municipalities in surrounding areas. The treatment plant, which is described in the Allegheny County Sanitary Authority's report of January 1948 titled "Proposed Collection and Treatment of Municipal Sewage and Industrial Wastes" (hereafter designated as the ACSA Report), consists of primary treatment with pre-aeration and chlorination. The initial objection of the ACSA is to provide sufficient treatment of its wastes to maintain a minimum of 2-3 ppm dissolved oxygen in the river and thereby prevent muisance conditions. The Ohio River Valley Water Sanitation Commission (ORSANCO) has recommended 4 ppm dissolved oxygen as a desirable minimum objective in the interstate portions of the upper Ohio River. In ORSANCO's report of March 1953 titled "Ohio River Pollution Abatement Needs, Pittsburgh-Huntington Stretch" it is stated that if loads were to increase materially over those estimated as of 1950-52 the minimum DO in the river would be reduced to an undesirable level. ORSANCO estimated the load from the Pittsburgh area to be about 316,000 lb. per day of 5-day B.O.D. as of 1950-52. In the ACSA Report, loads were estimated to be about 438,000 lbs. per day of 5-day B.O.D. in 1965 (175 MGD at 300 ppm) and 626,000 lbs. per day of 5-day B.O.D. in the year 2000 (250 MGD at 300 ppm).

Using design data supplied by the Allegheny County Sanitary

Authority, a series of calculations was performed in order to estimate the degree of treatment that would be required for design loads under various assumed river conditions. River discharges used in these calculations were seven-day mean low-flows that may be expected to occur once in ten years. These flows were obtained from a low-flow frequency analysis for the Ohio River at Sewickley, Pa. which was prepared by the Pittsburgh District Office, Corps of Engineers (See Figure 11). Without any low-flow augmentation the once in ten year seven-day mean low-flow is 1750 cfs. Existing low-flow augmentation (from Tygart, Youghiogheny, and East Branch Reservoirs) has increased this to 2650 cfs and the Allegheny Reservoir will increase it further to about 5000 cfs. Based upon the above discharges and loads estimated for the year 1965 by the Allegheny County Sanitary Authority, it has been estimated that, unless low-flow augmentation is provided from the Allegheny Reservoir, complete treatment will be required at Pittsburgh to maintain a minimum dissolved oxygen concentration of 4 ppm in the river. If low-flow augmentation is provided from the Allegheny Reservoir a lesser degree of treatment, probably chemical precipitation, should be sufficient to maintain a minimum dissolved oxygen concentration of 4 ppm in the river. Benefits to pollution abatement in the Pittsburgh area have been estimated on the basis of the difference in operation and amortized capital cost between providing complete and chemical sewage treatment. Construction and annual operating cost estimates prepared by the ACSA for the present plant as of July 1947 have been revised to represent present conditions in accordance with the appropriate Engineering News Record cost indices. Construction and operating costs have been estimated for both chemical precipitation and

complete treatment. Annual charges have been determined by amortization of capital costs over a 25 year period at 3½% interest. These cost estimates are presented in Table 3.

Table 3

Pollution Abatement Cost Analysis
(Pittsburgh Area)

Treatment	Capital Cost	Annual Charge (25 years at 3½%)	Annual Operation Cost	Total Annual Cost
Present Plant	$24,000,000	$1,460,000	$1,250,000	$2,710,000
Chemical Precipitation	$28,800,000	$1,750,000	$1,440,000	$3,190,000
Complete	$34,800,000	$2,110,000	$1,790,000	$3,900,000

Based on the foregoing considerations, benefits to pollution abatement in the Pittsburgh area resulting from low-flow augmentation from the Allegheny Reservoir should be about $710,000 per year.

Intangible benefits to pollution abatement will occur throughout the Allegheny and Ohio Rivers as a result of the proposed low-flow augmentation. Since sewage treatment processes must be considered stepwise as far as B.O.D. removal is concerned, low-flow augmentation may result in material improvements in water quality without corresponding decreases in the required degree of treatment. Tangible benefits may be allocated only if augmentation results in a reduction or elimination of treatment requirements in excess of primary treatment. The only exception involves the case of a chemical precipitation treatment plant in which low-flow

augmentation may result in a decrease in chemical usage even though there is no change in the required type of plant. The City of Cincinnati has under construction at present a chemical treatment plant. Augmentation by the Allegheny Reservoir will result in an increase in the flow in the Ohio River at Cincinnati during dry weather periods. Based upon previous studies of the effect of such flow increases, it has been estimated that a saving of about $20,000 per year in chemical costs for sewage treatment in the Cincinnati area may be allocated as a benefit to low-flow augmentation from the Allegheny Reservoir.

Public Water Supplies

In Table 4 are listed public water supplies using water from the Allegheny River below its confluence with the Clarion River. There are 13 such supplies serving a population of 552,800 an average of 155.90 million gallons of water daily.

The quality of Allegheny River water above the Clarion River is generally very good and presents no particular problems to water users. The Clarion River contributes a heavy organic pollution load to the Allegheny River below Foxburg. This load is due principally to wastes from pulp and paper mills and tanneries near the headwaters. These wastes have frequently caused taste, odor, and color problems at water plants on the Allegheny River as far downstream as Pittsburgh. There are three public water supplies on the Allegheny River between the Clarion and Kiskiminetas Rivers serving a population of 11,700 an average of 2.12 million gallons of water daily (Table 4). The Kiskiminetas River, which enters the Allegheny 30.1 miles above Pittsburgh, is the chief source of

Table 4

PUBLIC WATER SUPPLIES [1]

Allegheny River below Clarion-Allegheny Confluence

Name and Location	River Mile[2]	Treatment [3]	Population Served	MGD
City of Pittsburgh Dept. of Water Pittsburgh	8.0	P[4]-D-F	260,000	121.40
Wilkinsburg-Penn Joint Water Authority Wilkinsburg	8.5	P-D-F-T	175,000	16.70
Fox Chapel Authority Fox Chapel	10.0	P-D-F-T	7,000	0.59
Municipal Authority Boro of Oakmont Verona	12.8	P-D-T	30,000	4.33
West Penn Power Company Springdale	-	P-D	1,700	1.78
Municipal Authority City of New Kensington New Kensington	21.0	P-D-F-T	35,000	4.95
Tarentum Municipal Water Wks. Tarentum.....	21.7	P-D-T	12,000	1.52
Brackenridge Boro Munic. Water Works Brackenridge	22.5	P-D	7,000	1.19
Natrona Water Company Natrona	24.6	P-D-F	10,000	0.97
Freeport Water Company Freeport	29.3	P-D	3,400	0.35
(Kiskiminetas River)	30.1	-	-	-
Allegheny River Mining Co. Cadogan	38.5	P-D	730	0.04
Armstrong Water Company Kittanning	45.6	P-D-T	10,000	2.00
Parker City Munic. Authority Parker City	84.0	P-D	1,000	0.08
(Clarion River)	86.1	-	-	-

(1) Data from Pennsylvania Dept. of Health, Division of San. Engineering, Region III office and Region IV office.
(2) Miles above mouth of Allegheny River.
(3) P - purification plant - coagulation, sedimentation, filtration (rapid sand).
D- disinfection - chlorination
T - taste and odor control
F - fluoridation
(4) Slow sand filtration

mineral pollution in the lower Allegheny River. The water has a high acid content, due mostly to acid mine drainage and is the main cause of corrosion problems in the lower Allegheny River. The Kiskiminetas also contributes considerable hardness to the main stream and is the chief source of manganese problems in downstream water supplies. There are 10 public water supplies located on the Allegheny River between its confluence with the Kiskiminetas River and its mouth at Pittsburgh. These supplies serve a population of 541,100 an average of 153.78 million gallons of water daily (Table 4). Benefits to public water supplies resulting from the proposed low-flow augmentation have been limited in this report to those supplies using water from the Allegheny River below its confluence with the Kiskiminetas River. It is believed that any benefits occurring above the Kiskiminetas River would result principally from taste and odor reduction. Benefits of this nature are extremely difficult to evaluate economically and will be included as intangible benefits.

Principal water treatment problems in the lower Allegheny River are associated with the occurrence of acidity and manganese in raw water supplies. Low-flow augmentation from the Allegheny Reservoir will materially reduce the concentrations of these constituents during critical low-flow periods, resulting in a reduction in treatment costs. Practically none of the water produced by public water supplies on the lower Allegheny River is softened. Low-flow augmentation will, however, result in hardness reductions in raw water supplies with coincident benefits to water consumers. Benefits attributable to reductions in manganese, acidity, and hardness resulting from low-flow augmentation have been estimated.

Method of Analysis

Benefits to municipal water supplies were determined as the cost of treatment to obtain a reduction in hardness, manganese, or acidity equivalent to that obtained by dilution. Daily raw water quality data were obtained from the Aspinwall Filtration Plant of the City of Pittsburgh and from the Wilkinsburg-Penn joint water authority for the ten year period 1947-1956 inclusive. These data were used to represent the present water quality of the Allegheny River below its confluence with the Kiskiminetas River. Daily operating records were obtained from the same plants and were used as a basis for determining the cost of manganese removal and acid neutralization.

When storage in the Allegheny Reservoir is in Zone F (maximum low-flow regulation storage, Figure 1) it will be possible to maintain a minimum continuous discharge of 5,000 cfs at Lock 4 on the Allegheny River. Since this is the largest minimum continuous discharge that can be maintained, only those discharges less than 5,000 cfs will be affected by low-flow regulation releases from the Allegheny Reservoir. Daily discharge records were obtained from USGS Water Supply Papers for the Allegheny River at Natrona, Pennsylvania. This gaging station is located just above the dam at Lock 4 on the Allegheny River. All daily discharges less than 5,000 cfs occurring in the Allegheny River during the period 1947-1956 were tabulated. Hardness, manganese, and acidity concentrations were determined from the treatment plant records and tabulated for each of the above discharges. These concentrations were then diluted for each of four minimum continuous flow conditions. All discharges less than 5,000 cfs

were diluted to 5,000 cfs and, similarly, all flows less than 4,000 cfs, 3,000 cfs, and 2,000 cfs were diluted to these flows respectively. The augmenting water was assumed to contain 50 ppm total hardness, 5 ppm acidity (measured to cold phenolphthalein end point), and no manganese. Dilution water quality was based on an extensive study of USGS water quality data for the Allegheny River at Warren, Pennsylvania and at Kittanning, Pa., and daily water quality records obtained from the Armstrong Water Company at Kittanning, Pa. Actual reductions in hardness, acidity, and manganese concentrations were obtained for each minimum continuous flow condition. Frequency analyses were performed on the reduction data to determine the average number of days per year that reductions would have been obtained and the average value of the reductions. When combined with treatment costs and water usage the average yearly benefit was determined for each minimum continuous flow condition. These benefits represent the saving in treatment cost that would result if a minimum continuous discharge of 2,000, 3,000, 4,000, or 5,000 cfs were maintained for an entire year. The benefits so obtained have been pro-rated according to the percentage of time that each minimum flow can be maintained. It is believed, that by taking a ten-year period of record, benefits have been obtained which will represent the worth of the low-flow regulation function of the Allegheny Reservoir without placing undue emphasis upon any particular natural flow condition. There will be great variations in benefits from year to year but the values obtained in the foregoing manner are believed to represent average conditions that may be expected over a long period of time.

Manganese

Manganese is undesirable in public water supplies because it deposits on food during cooking and stains and discolors laundry and plumbing fixtures. Concentrations as low as 0.1 ppm have been reported as causing laundry trouble. In general, limiting concentrations from 0.1 to 0.5 ppm have been recommended. The U. S. Public Health Service Drinking Water Standards of 1946 recommended a limiting concentration of 0.3 ppm of iron and manganese together.

During the ten year period 1947-1956 daily manganese concentrations at Wilkinsburg varied from 0.2 ppm to 7.5 ppm with an average value of about 1.2 ppm. During the periods 1947-1950 and 1952-1956, daily manganese concentrations at Aspinwall varied from 0.0 ppm to 6.8 ppm with an average value of about 0.7 ppm.

An analysis of reductions in manganese concentrations was performed in accordance with the method previously described (p. 18). The results of this analysis are presented in Table 5. This table indicates the average number of days per year that manganese reductions may be expected to occur if minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs are maintained at Lock 4, Allegheny River, by augmentation from the Allegheny Reservoir. It also indicates the average manganese reduction that will occur and the resulting saving in treatment costs.

Table 5

Benefits to Public Water Supplies
Manganese Reduction

Minimum Continuous Discharge at Lock 4, Allegheny River (cfs)	Avg. No. Days per Year Mn Reduction will occur	Average Mn Reduction (ppm)	Annual * Benefit
2,000	30	0.30	$4,000
3,000	72	0.60	$19,000
4,000	93	0.78	$31,000
5,000	106	0.89	$41,000

* Based on total water consumption of 153.78 MGD.

Hardness

Hardness over 100 ppm becomes increasingly objectionable in public water supplies. Detrimental effects of hardness include excessive soap consumption, the formation of scums and curds, the toughening of vegetables cooked in hard water, the formation of scales in hot water heaters, pipes and utensils, and decreasing life of washable materials.

Public water supplies using Allegheny River water are generally not softened. This does not indicate, however, that there is no demand for softened water. Information obtained from the National Association of Soft Water Service Operators indicates that there are from 35,000 to 60,000 household softening units installed in Pittsburgh and its immediate suburbs. Public water supplies in the Pittsburgh area using Monongahela River water are softened. It seems reasonable to assume, therefore, that at least

some and possibly most of the household softening units are on services using Allegheny River water. While low-flow augmentation would not eliminate the need for household softening units it might decrease the cost of operation and maintenance of such units.

Benefits to public water supplies as a result of hardness reductions have been estimated on the basis of the cost of treatment to obtain a reduction equivalent to that obtained by dilution. Since water supplies on the Allegheny River are not softened at present, this method of analysis represents an approximation of a decrease in damages resulting from excessively hard water, rather than an actual saving in treatment plant operation.

During the ten year period 1947-1956 daily total hardness concentrations at Wilkinsburg varied from 40 ppm to 260 ppm with an average value of about 116 ppm. During the periods 1947-1950 and 1952-1956 daily total hardness concentrations at Aspinwall varied from 30 ppm to 320 ppm with an average value of about 100 ppm.

An analysis of hardness reductions has been performed in accordance with the method previously described (p.18). The results of this analysis are presented in Table 6. This table indicates the average number of days per year that hardness reductions may be expected to occur if minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs are maintained at Lock 4, Allegheny River, by augmentation from the Allegheny Reservoir. It also indicates the average hardness reduction that will occur for each period and the resulting decrease in damages due to excessive hardness, expressed as the cost of equivalent treatment.

Table 6

Benefits to Public Water Supplies
Hardness Reduction

Minimum Continuous Discharge at Lock 4, Allegheny River (cfs)	Avg. No. Days per Year Hardness Reduction Will Occur	Avg. Hardness Reduction (ppm)	Annual * Benefit
2,000	30	20	$18,000
3,000	72	42	$90,000
4,000	93	54	$150,000
5,000	106	61	$193,000

* Based on total water consumption of 153.78 MGD

Acidity

Acidity cannot be a direct or specific pollutant since it is merely a measure of the effects of a combination of substances and conditions in water. It may be defined as the power of a water to neutralize hydroxyl ions, and it is expressed in terms of the calcium carbonate equivalent of the hydroxyl ions neutralized. Acidity is usually caused by the presence of free carbon dioxide, mineral acids such as sulfuric, weakly dissociated acids such as phosphoric which affect the buffering action, and salts of strong acids and weak bases. Acidity should not be confused with pH value since one water with a pH of 6.0 may have a low total acidity (acidity to phenolphthalein end point) whereas another highly buffered water with a pH of 7.0 may have a high total acidity. The U. S. Public Health Service Drinking Water Standards of 1946 do not specify limiting values for

acidity. Excessive acidity is frequently detrimental in waterworks operation in that it must be neutralized to prevent corrosion.

The Allegheny River above the Kiskiminetas River is an alkaline stream. The Kiskiminetas River is highly acid, due primarily to acid mine drainage, and is the principal cause of acidity in the lower Allegheny River.

During the ten year period 1947-1956 daily concentrations of total acidity at Wilkinsburg ranged from 2 ppm to 51 ppm with an average value of about 7.7 ppm. This acidity is reported as total acidity and is measured by titration to the phenolphthalein end point. This titration is carried out at room temperature and therefore includes, in addition to mineral acidity, the effect of carbon dioxide as well as other non-mineral acids. A water may be alkaline but as long as its pH is below 8.3 (the phenolphthalein end point) some acidity will be present when measured in this manner. In determining reductions in acidity it was assumed that the diluting water had an acidity of 5 ppm.

An analysis of acidity reductions was performed in accordance with the method previously described (p. 18). The results of this analysis are presented in Table 7. This table indicates the average number of days per year that acidity reductions may be expected to occur if minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs are maintained at Lock 4, Allegheny River, by augmentation from the Allegheny Reservoir. It also indicates the average acidity reduction that will occur for each period and the resulting saving in treatment cost.

Table 7

Benefits to Public Water Supplies
Acidity Reduction

Minimum Continuous Discharge at Lock 4, Allegheny River (cfs)	Avg. No. Days per Year Acidity Reduction Will Occur	Average Acidity Reduction (ppm)	Annual * Benefit
2,000	8	2.3	$1,000
3,000	31	2.8	$4,000
4,000	46	3.0	$7,000
5,000	57	3.2	$9,000

* Based on total water consumption of 153.78 MGD

It may be seen from the above table that the number of days per year that acidity reductions will occur is considerably less than the corresponding figures for hardness and manganese reductions. Acidities in the lower Allegheny River are generally quite low and as a result there are many occasions when no measurable reduction will occur even though low-flow augmentation is being provided. The greatest problem with respect to acidity in the lower Allegheny River is the periodic discharge of slugs of acidity from the Kiskiminetas River. Such discharges may kill aquatic life and impose a distinct economic burden on water works operation. Low-flow augmentation will help to reduce the severity of these periodic discharges from the Kiskiminetas River. While this effect is not capable of direct economic evaluation, it will represent a very real economic benefit.

Industrial Water Supplies

The study of benefits to industrial water supplies resulting from low-flow augmentation by the Allegheny Reservoir has been limited, with two exceptions, to those industrial supplies on the Allegheny River below its confluence with the Kiskiminetas River and on the Ohio River within the State of Pennsylvania. Water quality problems on the lower Allegheny River have been discussed previously in the section on benefits to public water supplies. The quality of water in the upper Ohio River is greatly influenced by the discharge of acid water from the Monongahela River. Acid mine drainage is the principal cause of the poor quality of the Monongahela River, although it is also quite heavily polluted with municipal and industrial wastes.

Principal problems involving the quality of industrial water supplies on the lower Allegheny and upper Ohio Rivers are associated with the occurrence of hardness and acidity. Low-flow augmentation from the Allegheny Reservoir will materially reduce the concentrations of these constituents during critical low-flow periods, resulting in direct benefits to industrial water users. In addition to the above, benefits have been estimated for those industries using river water for cooling. Low-flow augmentation will result in a decrease in river water temperatures which will be reflected in an increase in the efficiency of industrial cooling systems.

Hardness

Excessive hardness is undesirable in many industrial water supplies such as laundries, carbonated beverages, metal finishing, dyeing and

textile industries, food processing, pulp and paper, photography, and leather goods. In addition to being unsatisfactory for the above uses, hard water when heated causes the formation of scale in waterpipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale from 1/50 to 1/9 inch thick has been reported to be from 7 to 16 per cent. To this loss in efficiency must be added the cost of periodic draining of cooling systems, the cost of scale removal, and the cost of production time lost as a result of these depositions.

Hardness requirements for various industrial processes vary considerably. Industries contacted in the Pittsburgh area indicated maximum desirable hardness concentrations ranging from zero to 200 ppm. The amount of boiler and process water obtained by industry directly from the Allegheny and upper Ohio Rivers was determined by contacting industries suggested by the Pennsylvania Department of Health. Information obtained in this manner indicated that the chief benefits due to hardness reduction would occur on the Ohio River where somewhat more than 91 MGD is reported to be taken from the river by industry for boiler and process water. No benefits were estimated for hardness reduction in cooling water.

Water quality data for the Ohio River at Ambridge, Pa. were obtained from U.S.G.S. Water Quality Papers for the water years 1946, 1947, 1950, 1951, and 1952. These data showed hardnesses varying from 40 ppm to over 300 ppm.

Benefits to industrial water supplies as a result of hardness reductions were estimated in accordance with the method previously described for public water supplies (page 18).

Annual benefits to industrial water supplies on the upper Ohio River are presented in Table 8. This table also indicates the number of days per year hardness reductions may be expected to occur in the Ohio River if minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs are maintained on the Allegheny River at Lock 4, and the average reduction for each minimum discharge. Benefits were estimated as the cost of softening to reduce the hardness in an amount equivalent to the reduction obtained by dilution.

Table 8

Benefits to Industrial Water Supplies On The Upper Ohio River

Hardness Reduction

Minimum Continuous Discharge (Allegheny River) (cfs)	Avg. No. Days per Year Hardness Reduction Will Occur	Avg. Hardness Reduction (ppm)	Annual * Benefit
2000	30	9	$ 5,000
3000	72	30	$ 38,000
4000	93	37	$ 61,000
5000	106	46	$ 86,000

* Based on boiler and process water usage = 91 MGD

Acidity

Acidity as a pollutant has been described previously (page23). Limits for acidity in industrial water supplies are seldom encountered

since such restrictions are usually expressed in terms of pH values.

The major damages reported in the past to be attributable to acidity in the waters of the Allegheny, Monongahela, and Ohio Rivers were associated with corrosion in steam-electric power plants. Industries contacted during this study indicated that, while installations on the Monongahela River are still being heavily damaged by corrosion, no such damages could be determined for installations on either the Allegheny or Ohio Rivers. New alloy metals seem to have successfully mitigated corrosion damages previsouly associated with the relatively low acid concentrations occurring in the Allegheny and upper Ohio Rivers. Some benefits to industrial water supplies will undoubtedly result from reductions in acidity on the Allegheny and Ohio Rivers. Due to the difficulty of evaluation, these benefits will be included as intangible.

Water Temperature

The most recent available information on industrial use of surface water in the Pittsburgh area, other than that obtained by direct correspondence with industries, was published by the U. S. Geological Survey in Circular No. 315, "Water Resources of the Pittsburgh Area, Pennsylvania." It was reported that industry used an average of 2,800 MGD of surface water from private supply systems in 1951. More than 57% of this water was used for cooling in steam-power generation and more than 41 per cent was used in the manufacture of iron, steel, and allied products. No accurate estimates are available regarding the volumes of industrial water supplies taken from individual rivers in the Pittsburgh area. For the

purposes of this investigation it has been assumed that 800 MGD is taken from the Monongahela River and that the remaining 2000 MGD is equally divided between the Allegheny and Ohio Rivers.

In a heavily industrialized area such as Pittsburgh the discharge of large volumes of cooling water to the rivers causes a material increase in water temperatures, particularly during periods of low-flow. Operation of the Allegheny Reservoir for low-flow augmentation will cause a measurable reduction in the mangitude of these temperature increases. The efficiency of industrial cooling systems depends primarily upon the temperature differential between the cooling water and the substance being cooled. An increase in this temperature differential, within limits, will result in decreasing the volume of cooling water required. It is recognized that cooling requirements vary considerably for different industries or processes. These variations have been considered in developing benefits due to temperature reductions resulting from low-flow augmentation. Benefits as estimated in Table 9 are believed conservative since they have been restricted to reductions in pumping costs. Steam electric generating plants use large volumes of cooling water. The efficiency of such plants is also influenced by cooling water temperatures although the optimum cooling water temperature is a function of the design of the specific plant. Benefits due to temperature reductions as estimated in Table 9 include benefits to steam electric generating plants as well as benefits to other industrial cooling systems.

The temperature of surface waters varies with air temperature, usually reaching a maximum in July or August. During periods when air

temperatures are above freezing and in areas where no significant volumes of municipal or industrial wastes are discharged to the water courses, it has been observed that monthly average surface water temperatures usually approximate monthly average air temperatures. In determining temperature reductions due to low-flow augmentation, the augmenting flows were assumed to have a temperature equal to the mean monthly air temperature during the month when the augmentation occurred. Monthly mean water temperatures for the Allegheny River at Aspinwall, Colfax, and Springdale and for the Ohio River at Brunot Island and McKees Rocks were obtained from U. S. Geological Survey Circular No. 315. Monthly mean air temperatures were obtained from the U. S. Weather Bureau. Discharge data for the period 1947-1955 for the Allegheny River at Natrona and the Ohio River at Sewickley were obtained from U. S. Geological Survey Water Supply Papers. Recorded discharges on the Allegheny River were augmented to provide minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs at Lock 4, Allegheny River. The average number of days per year that temperature reductions would occur on the Allegheny River and the average values of these reductions were determined for each minimum continuous discharge. In the Ohio River, benefits were based on average temperature reductions occurring each year during the three month period August to October.

Information obtained from industries in the Pittsburgh area indicated that savings in pumping costs for cooling water would amount to $0.20 per day per degree Fahrenheit temperature reduction per million gallons of cooling water used. Low-flow augmentation benefits due to temperature reductions are summarized in Table 9.

Table 9

Benefits to Industrial Water Supplies
Temperature Reduction

Minimum Continuous Discharge-Allegheny R. at Lock 4 (cfs)	Allegheny River			Ohio River		Total Annual Benefit
	No. days per year temp. reduction occurs	Avg. Temp. Reduction (°F)	Annual Benefit	Avg.* Temp. Reduction (°F)	Annual Benefit	
3,000	65	2.1	$27,000	0.6	$11,000	$38,000
4,000	84	3.0	$50,000	1.2	$22,000	$72,000
5,000	95	3.9	$74,000	1.8	$32,000	$106,000

* During the period August to October, inclusive.

Water released during warm summer periods from the lower levels of deep impoundments such as the Allegheny Reservoir will be considerably colder than would be the case under natural flow conditions. This effect is dissipated as the water passes downstream and has not been considered in the foregoing analysis. Industrial plants located sufficiently close to the reservoir will be benefitted by temperature reductions resulting from the discharge of cold water from the reservoir. There is a steam electric generating plant located about 10 miles downstream from the site of the Allegheny Reservoir. Conditions observed at other reservoirs and operating data for this plant have been evaluated. It is estimated that river water temperature reductions resulting from the discharge of water from the lower levels of the Allegheny Reservoir would result in the saving of about $4,000 annually in operation expense at this power plant.

Navigation

The corrosive action of acid waters in the lower Allegheny and Upper Ohio Rivers is of considerable concern to navigation interests. The Kiskiminetas River is highly acid and is the principal cause of acidity in the lower Allegheny River. The occurrence of acid conditions in the upper Ohio River is primarily attributable to acid discharges from the Monongahela River. Corrosive conditions result in damage to floating navigation plant (barges and tow boats) and to the submerged portions of fixed structures such as locks and dams, harbor facilities, and bridges.

Corrosion damages and benefits resulting from low-flow augmentation were estimated in the "Report of the United States Public Health Service on Ohio River Pollution Control" (House Document No. 266, 78th Congress). Considerable progress has been made by river transportation companies toward mitigating corrosion damages since these estimates were prepared in 1940. A large part of corrosion damages to navigation plant in 1940 was based upon operating experiences with steam powered tow boats. The trend toward the use of diesel powered boats has been such that damages to steam boats are no longer considered significant.

In 1954 a rather complete re-examination of the nature of corrosion damages to navigation interests was made by the U. S. Public Health Service in connection with a report on the Stonewall Jackson Reservoir, West Fork River. Benefits to navigation resulting from low-flow augmentation from the Allegheny Reservoir have been estimated using basic corrosion data obtained during the above study. Unit reductions in corrosion damages per ppm acidity reduction were determined for barges, tow boats, and

locks and dams. Acidity reductions were determined for the lower Allegheny and upper Ohio Rivers in accordance with the method previously described for public water supplies (p. 18). Information obtained from the Corps of Engineers, Pittsburgh District, indicates that the approximate numbers of barges used wholly or intermittently on the Allegheny and upper Ohio Rivers are 200 and 1,200 respectively. Exclusive of harbor tugs, there are approximately 25 tow boats moving wholly or intermittenly on the Allegheny River and 100 tow boats on the upper Ohio River. In addition to barges and tow boats, benefits were considered for locks and dams on the Allegheny River below the Kiskiminetas River and the Ohio River within the State of Pennsylvania.

The results of the analysis of benefits to navigation attributable to low-flow regulation are presented in Table 10. This table indicates the average number of days per year that acidity reductions may be expected to occur if minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs are maintained at Lock 4, Allegheny River, by low-flow augmentation from the Allegheny Reservoir. It also indicates the average magnitude of these acidity reductions and the resulting annual benefits to navigation expressed as a reduction in corrosion damages.

It should be noted that for each minimum continuous discharge maintained at Lock 4, Allegheny River, there will be more days per year that acidity reductions will occur on the Ohio River than on the Allegheny River. Most of the acid load in the upper Ohio River is attributable to discharges from the Monongahela River, and consequently there are many occasions when the upper Ohio River is considerably more acid than the Allegheny River.

Since augmenting discharges have been assumed to contain 5 ppm of total acidity (see p.25), it is apparent that low-flow augmentation may frequently cause a considerable reduction in acidity on the upper Ohio River when there is no measurable reduction in acidity on the lower Allegheny River.

Table 10

Benefits to Navigation
(Reduction in corrosion damages resulting from acidity reduction)

Minimum Continuous Discharge (Lock 4, Allegheny R.) (cfs)	Allegheny River			Ohio River			Total Annual Benefit
	No. days per year acidity reduction will occur	Average Acidity Reduction (ppm)	Annual Benefit	No. days per year acidity reduction will occur	Average Acidity Reduc-tion (ppm)	Annual Benefit	
2,000	8	2.3	-0-	19	1.6	$1000	$1000
3,000	31	2.8	$1000	55	3.9	$8000	$9000
4,000	46	3.0	$1000	74	5.4	$14000	$15000
5,000	57	3.2	$2000	95	6.2	$21000	$23000

Summary of Tangible Benefits

Benefits to pollution abatement, public and industrial water supplies, and navigation attributable to low-flow augmentation from the Allegheny Reservoir have been determined. With two exceptions, all benefits have been estimated on the basis of providing minimum continuous discharges of 2,000, 3,000, 4,000, and 5,000 cfs at Lock 4 on the Allegheny River. The exceptions to the above are benefits to pollution abatement and temperature reduction benefits to industrial water supply just below the reservoir. All estimated benefits are summarized in Table 11.

Table 11

Summary of Annual Tangible Benefits
for Various Augmented Discharges

	Minimum Continuous Discharge Maintained at Lock 4, Allegheny River			
	2000 cfs	3000 cfs	4000 cfs	5000 cfs
Public Water Supplies				
Manganese Reduction	$4,000	$19,000	$31,000	$41,000
Hardness Reduction	$18,000	$90,000	$150,000	$193,000
Acidity Reduction	$1,000	$4,000	$7,000	$9,000
Industrial Water Supplies				
Hardness Reduction	$5,000	$38,000	$61,000	$86,000
Temperature Reduction (cooling water)	---	$38,000	$72,000	$106,000
Navigation (Corrosion) (Reduction)	$1,000	$9,000	$15,000	$23,000
Pollution Abatement		$730,000		
Industrial Water Supply-Misc. Temperature Reduction		$4,000		

Flow duration curves for the Allegheny River at Natrona, Pennsylvania are presented in Fig. 12. After the Allegheny Reservoir is placed in operation, minimum continuous discharges of 2,000 cfs, 3,000 cfs, 4,000 cfs, and 5,000 cfs will be maintained 100%, 98%, 90% and 77% of the time respectively on the Allegheny River at Lock 4 (Natrona). Average annual benefits have been estimated by prorating the annual benefits for each

minimum continuous discharge in accordance with the percentage of time that each discharge will be maintained. If the annual benefits for minimum continuous discharges of 2,000 cfs, 3,000 cfs, 4,000 cfs, and 5,000 cfs are assumed to be B_2, B_3, B_4, and B_5 respectively, the average annual benefit is equal to $0.77 (B_5) + 0.13 (B_4) + 0.08 (B_3) + 0.02 (B_2)$. Average annual benefits are summarized in Table 12.

Table 12

Summary of Average Annual Tangible Benefits

Public Water Supplies		
Manganese reduction	$37,000	
Hardness reduction	176,000	
Acidity reduction	8,000	
Total		$221,000
Industrial Water Supplies		
Hardness reduction	$77,000	
Temperature Reduction (cooling water)	$98,000	
Total		$175,000
Navigation (corrosion reduction)		$20,000
Pollution Abatement		$730,000
Total		$1,146,000

INTANGIBLE BENEFITS

Many of the beneficial effects of low-flow augmentation are not capable of economic analysis and must be considered as intangible. Intangible benefits to pollution abatement, municipal and industrial water supplies, recreation, public health, and the general economy of the watershed may all be attributed to low-flow regulation. These benefits, while not capable of economic evaluation, will be of considerable magnitude.

Pollution Abatement

Low-flow regulation will result in benefits to pollution abatement throughout the Allegheny and Ohio Rivers insofar as increased discharge during low-flow periods will improve water quality below all sources of pollution. Tangible benefits may be allocated only when waste treatment requirements in excess of primary (or equivalent) are reduced or eliminated by low-flow regulation. Considerable improvements in water quality may occur as a result of augmentation even though the required degree of waste treatment is not reduced. The ultimate value of these improvements will be reflected in increasing the ability of the Allegheny and Ohio Rivers to assimilate the additional wastes resulting from future population growth and industrial expansion. It is conceivable that future load increases might be of such a magnitude that even the provision of a high degree of treatment would be insufficient to prevent degradation of river water quality below desired objectives. In this situation low-flow augmentation would be the only means of maintaining desirable river water quality.

Public and Industrial Water Supplies

Tangible benefits to public and industrial water supplies have been limited in this report to those benefits resulting from reductions in certain specific constituents. These benefits have been expressed as the cost of treatment to obtain reductions equivalent to those obtained by dilution.

Many of the benefits to public water supplies resulting from low-flow regulation are not capable of evaluation in the foregoing manner. One of the most important effects of low-flow regulation should be the maintenance of more uniform water quality in raw water supplies throughout the basin. This would simplify water works operation and lessen the chance of treatment processes being disrupted by widely fluctuating raw water quality. These effects may be considered to be general benefits to public health insofar as they simplify water treatment procedures and thereby help to assure delivery of uncontaminated water of a uniform quality to the consumer. Low-flow augmentation should help to mitigate taste and odor problems which are prevalent in water supplies on the lower Allegheny and upper Ohio Rivers. Such benefits, from an aesthetic point of view, should be of considerable magnitude. While these benefits are quite difficult to evaluate economically, it is apparent that the cost of developing an alternative water supply of better quality would be very great.

The effect of low-flow augmentation in providing more uniform water quality should result in large benefits to industrial water users

as well as to public supplies. Uniform water quality will simplify the treatment of industrial water supplies and will be of particular value in many industries where uniform process water quality is critical.

Recreation

It is believed that low-flow augmentation will result in improvements in water quality that will materially enhance the value of the Allegheny River for recreational uses. This effect will be felt throughout the entire reach of the Allegheny River below the reservoir, but the most important area affected will be the 30-mile reach below the Kiskiminetas River, which is now unsuitable for most recreational purposes. If anticipated improvements are realized it is expected that this portion of the river will become suitable for recreational activities such as fishing and boating. In addition, the creation of a large impoundment such as the Allegheny Reservoir will provide recreational opportunities not previously existent. Increased recreational activity throughout the Allegheny River Basin will be reflected in sales of boats, motors, trailers, camping equipment, and in the establishment of enterprises serving these activities such as resorts, motels, restaurants, boat docks, and other related businesses. The economic impact of these developments will be felt the entire length of the river from the reservoir site to Pittsburgh. The greatest effect upon the existing economy will, however, occur in the relatively uninhabited areas along the upper reaches of the river.

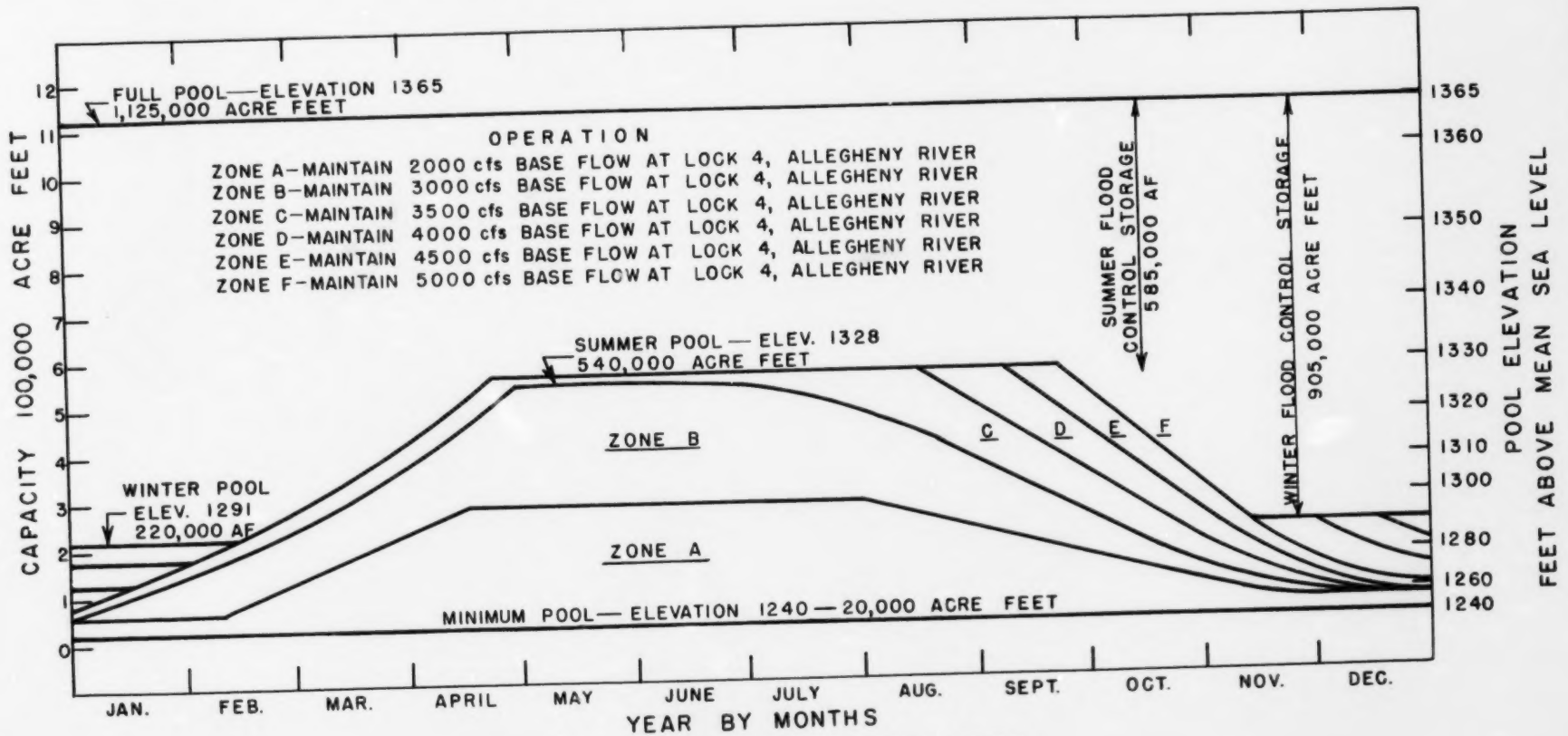
Economic Potentials

With the exception of the Pittsburgh area, the Allegheny River basin has not been intensively developed industrially. One of the primary factors in industrial location is the assurance of an adequate supply of high quality water. Low-flow augmentation from the Allegheny Reservoir will provide a larger assured supply of water throughout the length of the river. This would be of particular significance in the upper reaches of the river and would make this area much more attractive for industrial development. Improvements in water quality resulting from low-flow augmentation would enhance the usefulness of the entire river as a source of industrial water supply.

The foregoing considerations should constitute powerful incentives toward the ultimate realization of the industrial potential of the upper Allegheny River basin. Industrial expansion in this area would result in population increases, the establishment of new private enterprise, the enhancement of property values, and many other directly related economic advances.

The effect of low-flow augmentation in providing increased recreational opportunities has been discussed previously and should be included in any evaluation of the economic potentials of the Allegheny River basin.

APPENDIX

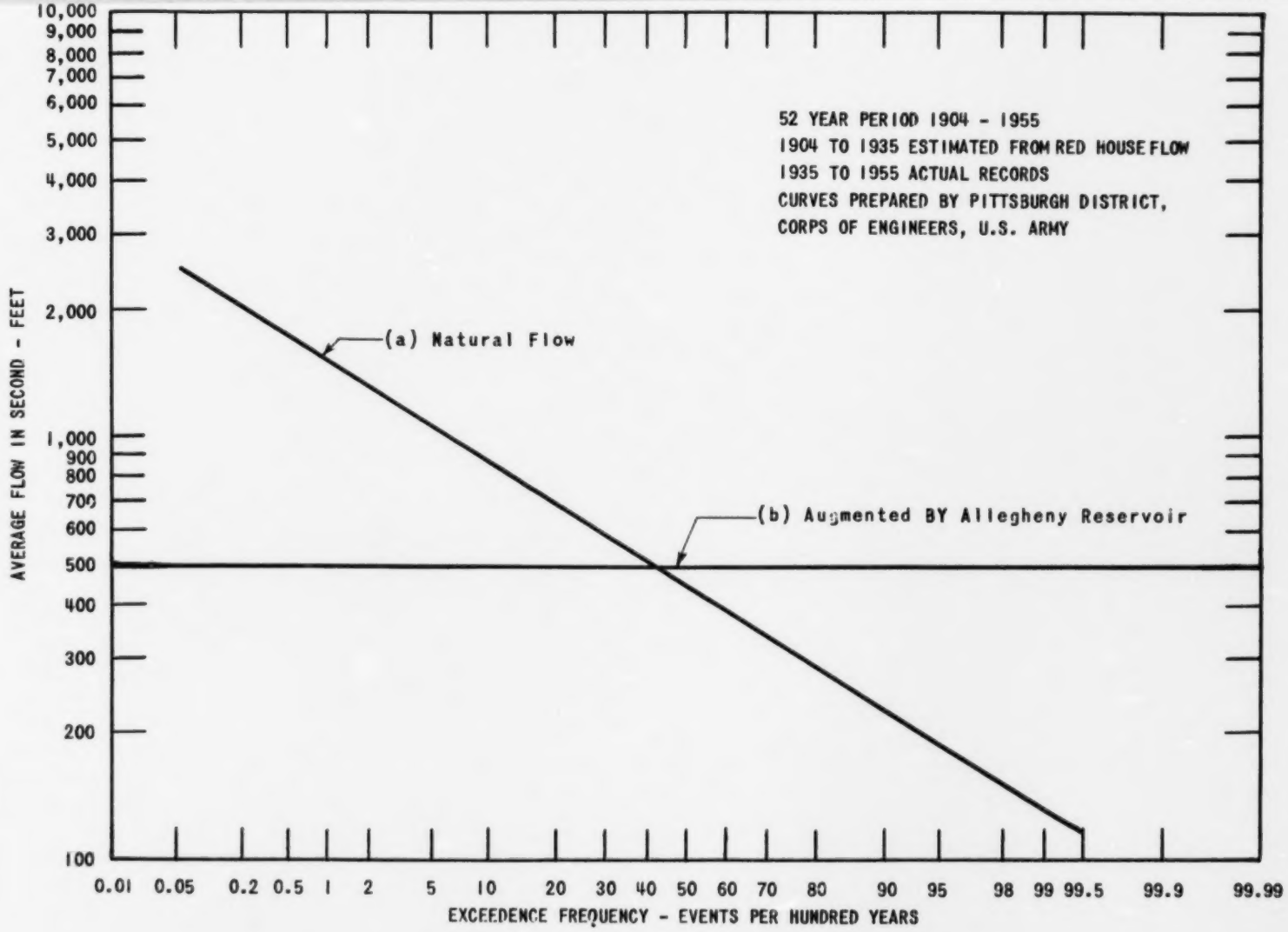


ALLEGHENY RIVER RESERVOIR

PRELIMINARY STORAGE ALLOCATION SCHEDULE

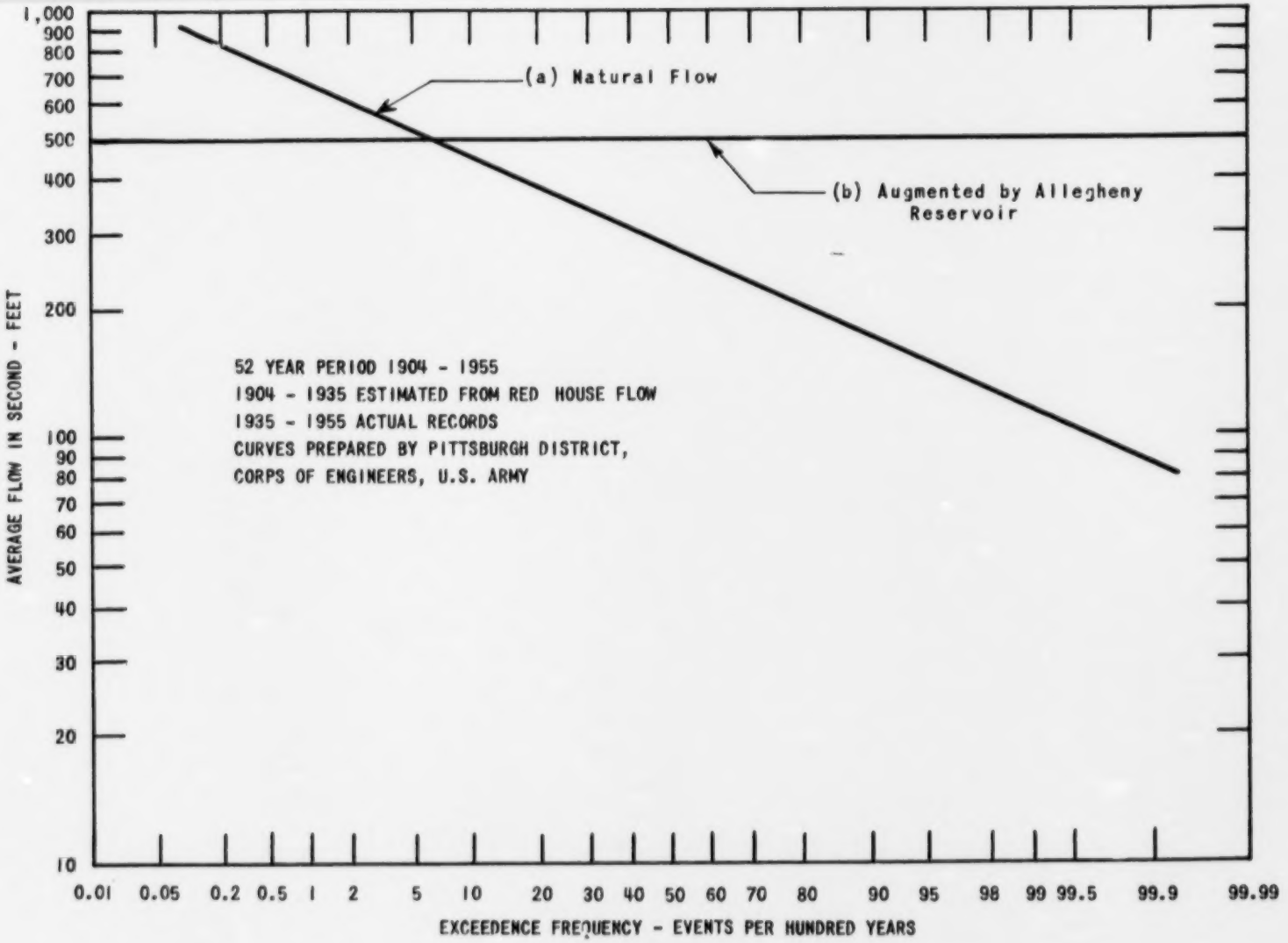
PREPARED BY PITTSBURG DISTRICT, CORPS OF ENGINEERS, U.S. ARMY

FIGURE 1



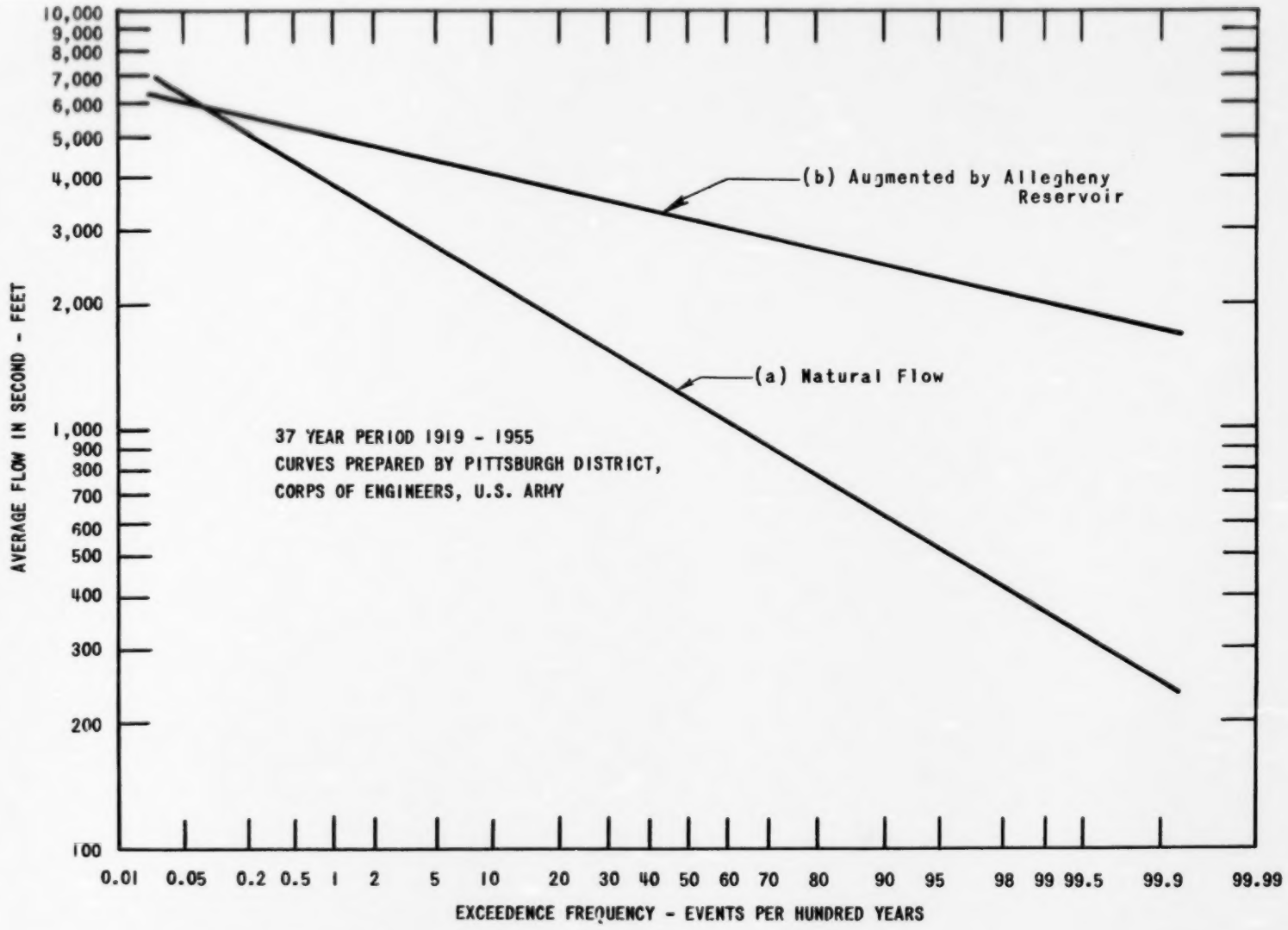
ALLEGHENY RIVER AT KINZUA, PA., LOW FLOW FREQUENCY
MONTHLY MEAN LOW FLOW

FIGURE 2



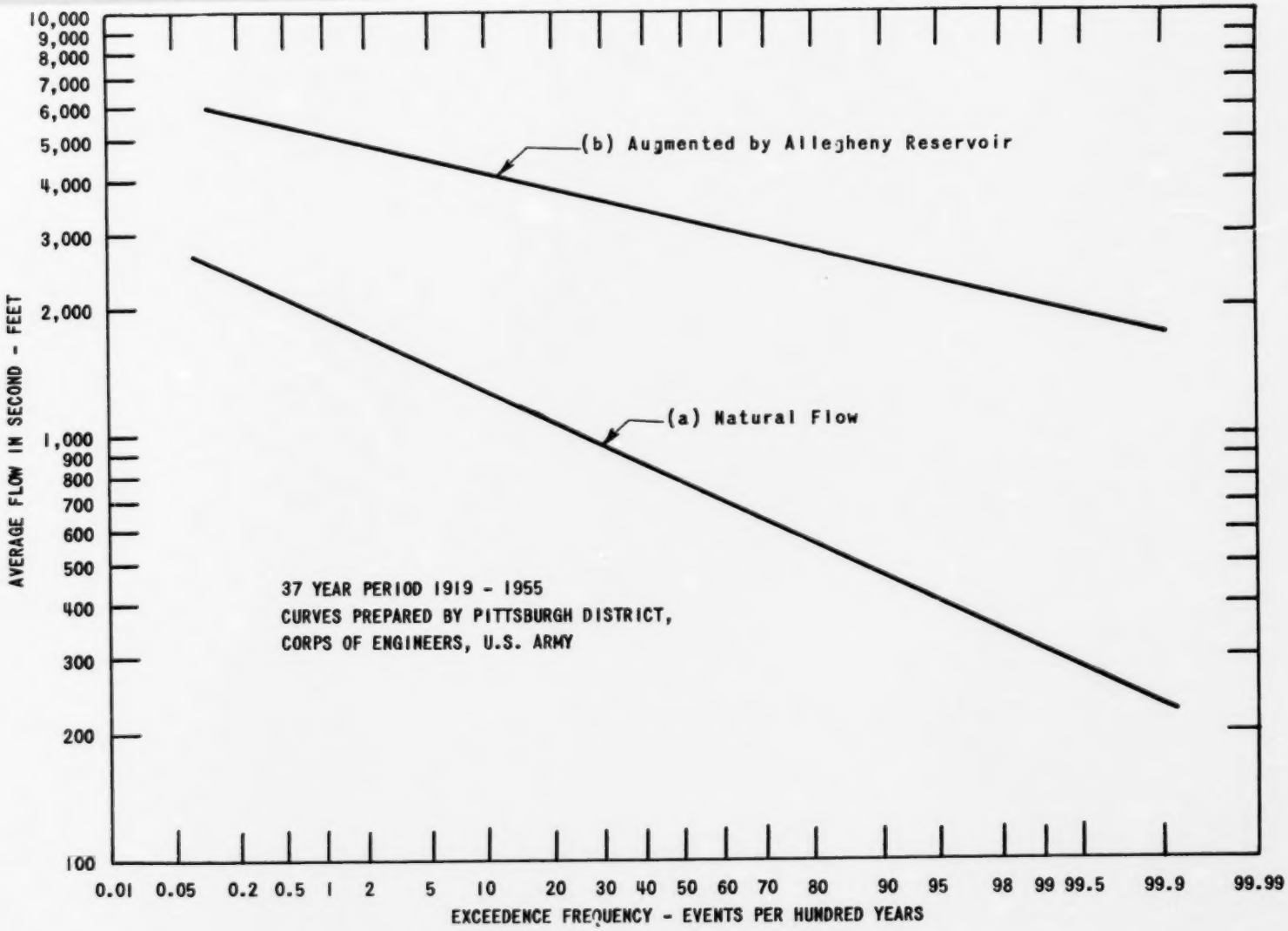
ALLEGHENY RIVER AT KINZUA, PA., LOW FLOW FREQUENCY
SEVEN DAY MEAN LOW FLOW

FIGURE 3



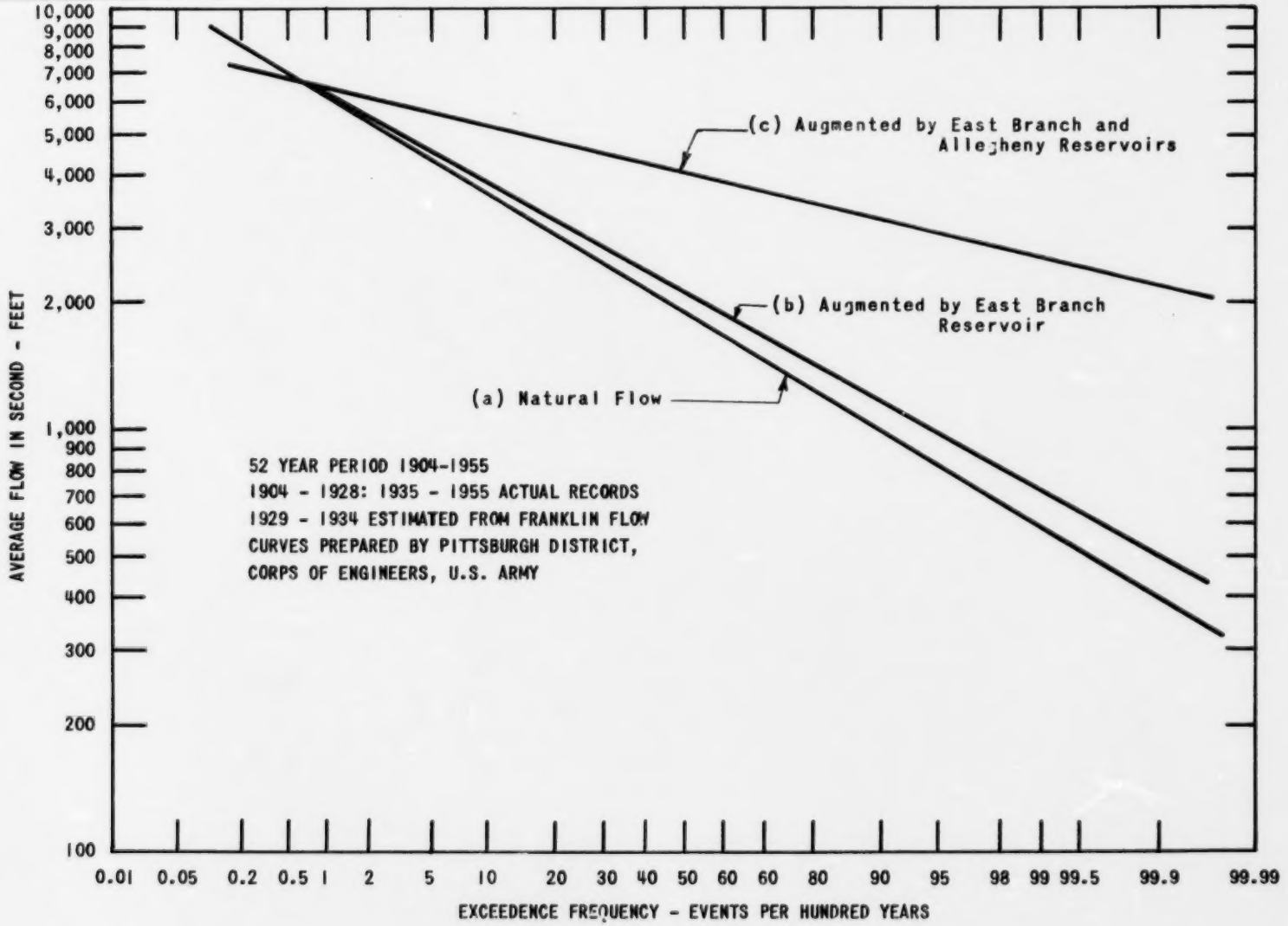
ALLEGHENY RIVER AT FRANKLIN, PA., LOW FLOW FREQUENCY
MONTHLY MEAN LOW FLOW

FIGURE 4



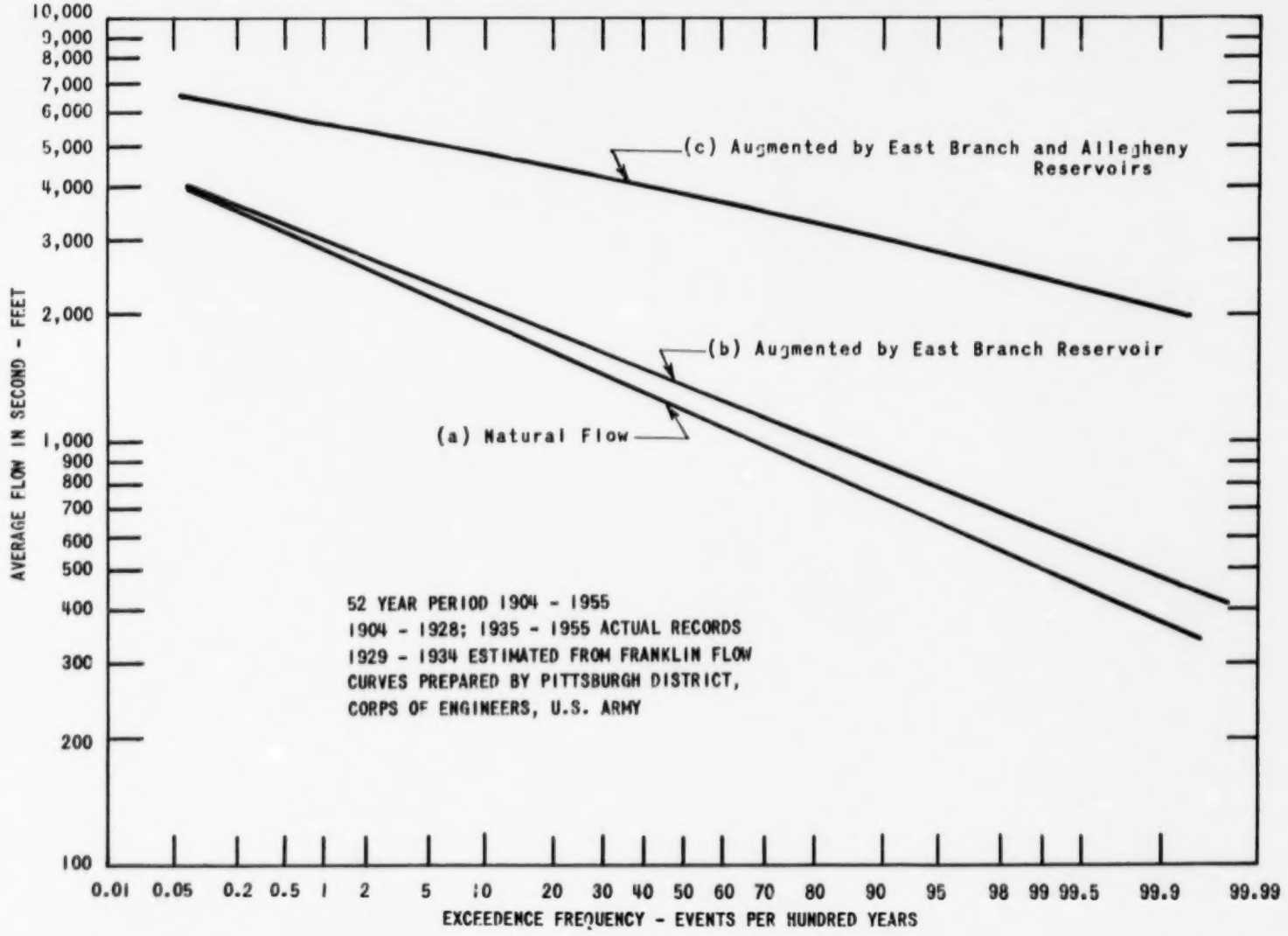
ALLEGHENY RIVER AT FRANKLIN, PA., LOW FLOW FREQUENCY
SEVEN DAY MEAN LOW FLOW

FIGURE 5



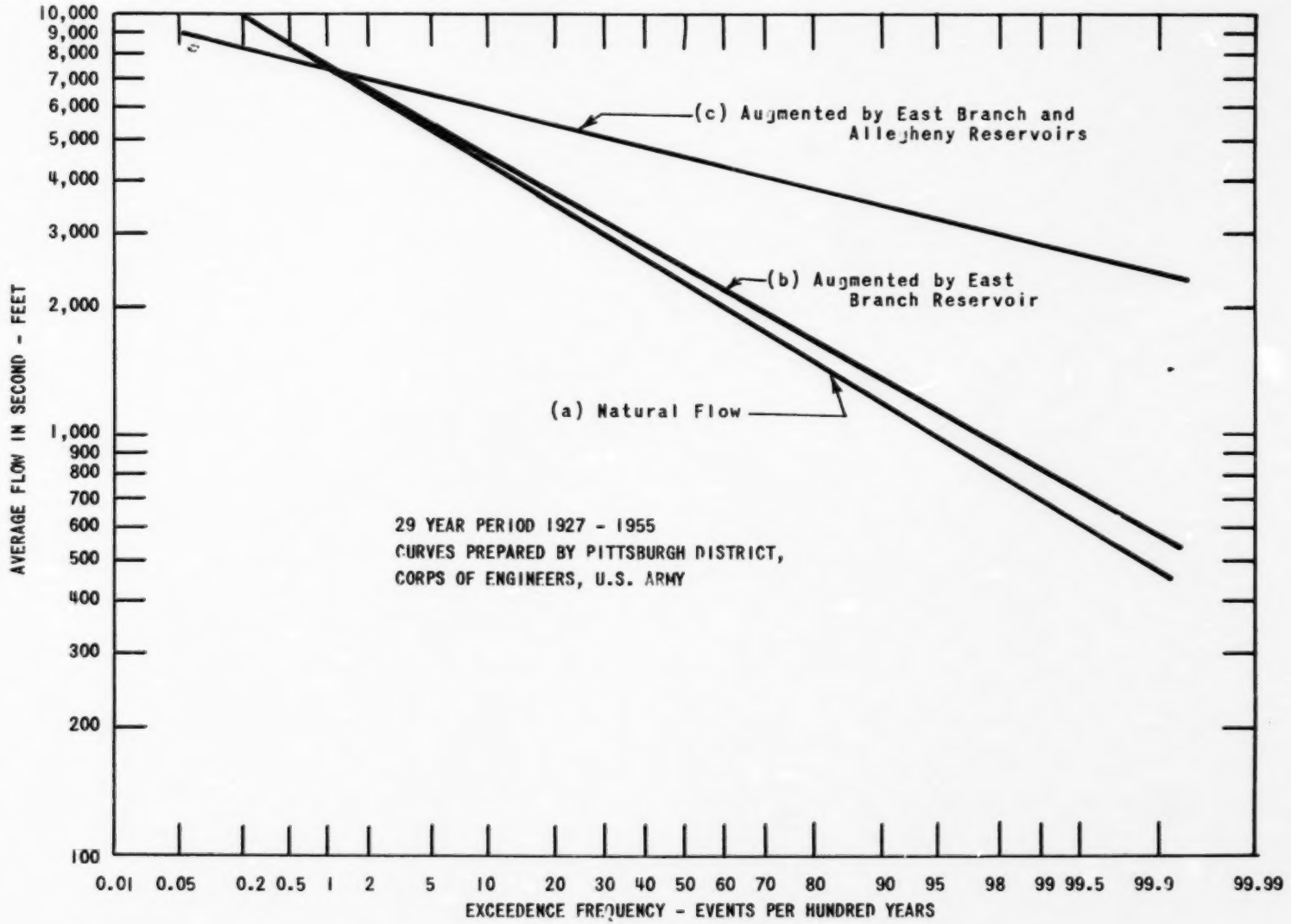
ALLEGHENY RIVER AT KITTANNING, PA., LOW FLOW FREQUENCY
MONTHLY MEAN LOW FLOW

FIGURE 6



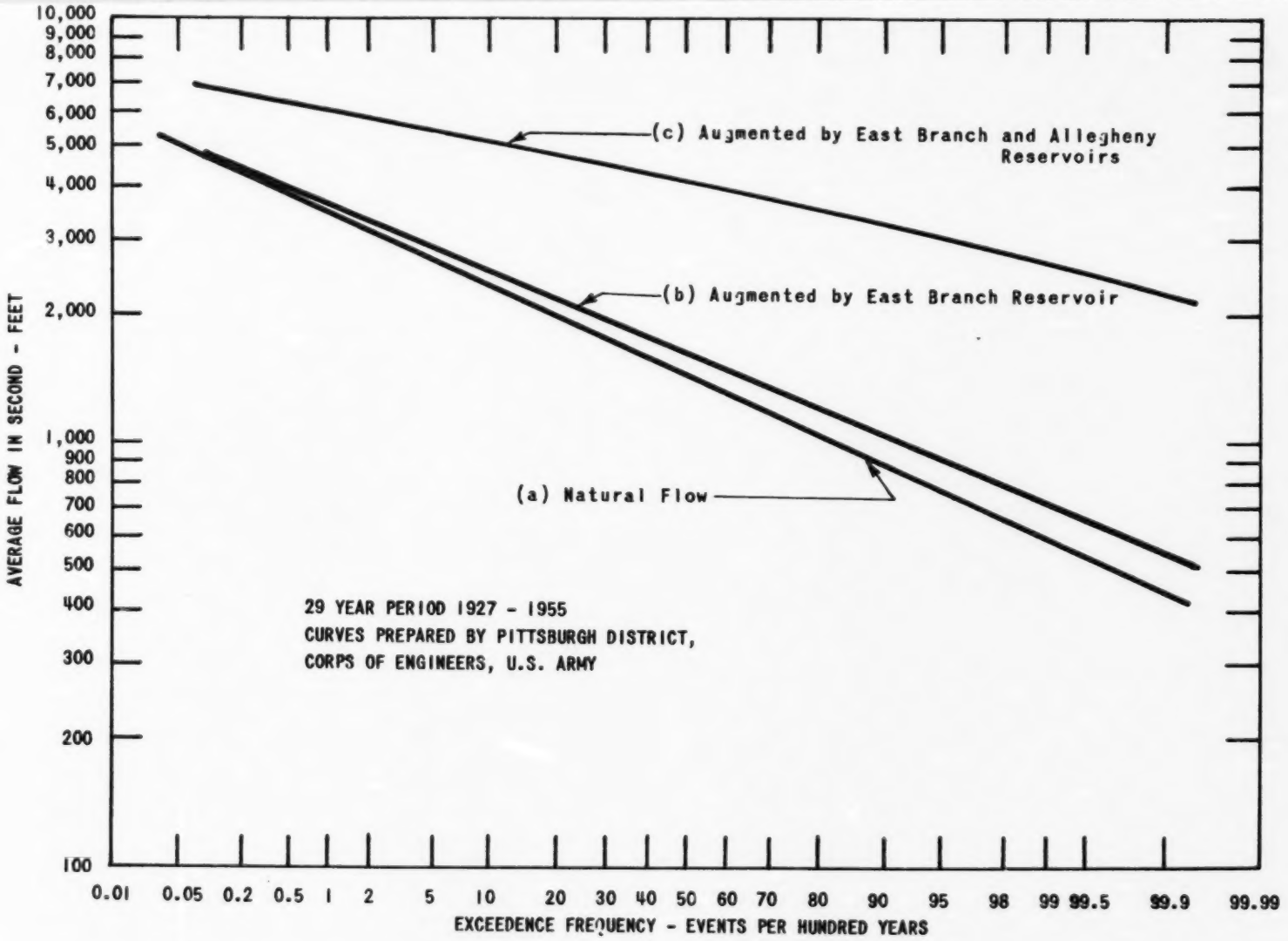
ALLEGHENY RIVER AT KITTANNING, PA., LOW FLOW FREQUENCY
SEVEN DAY MEAN LOW FLOW

FIGURE 7



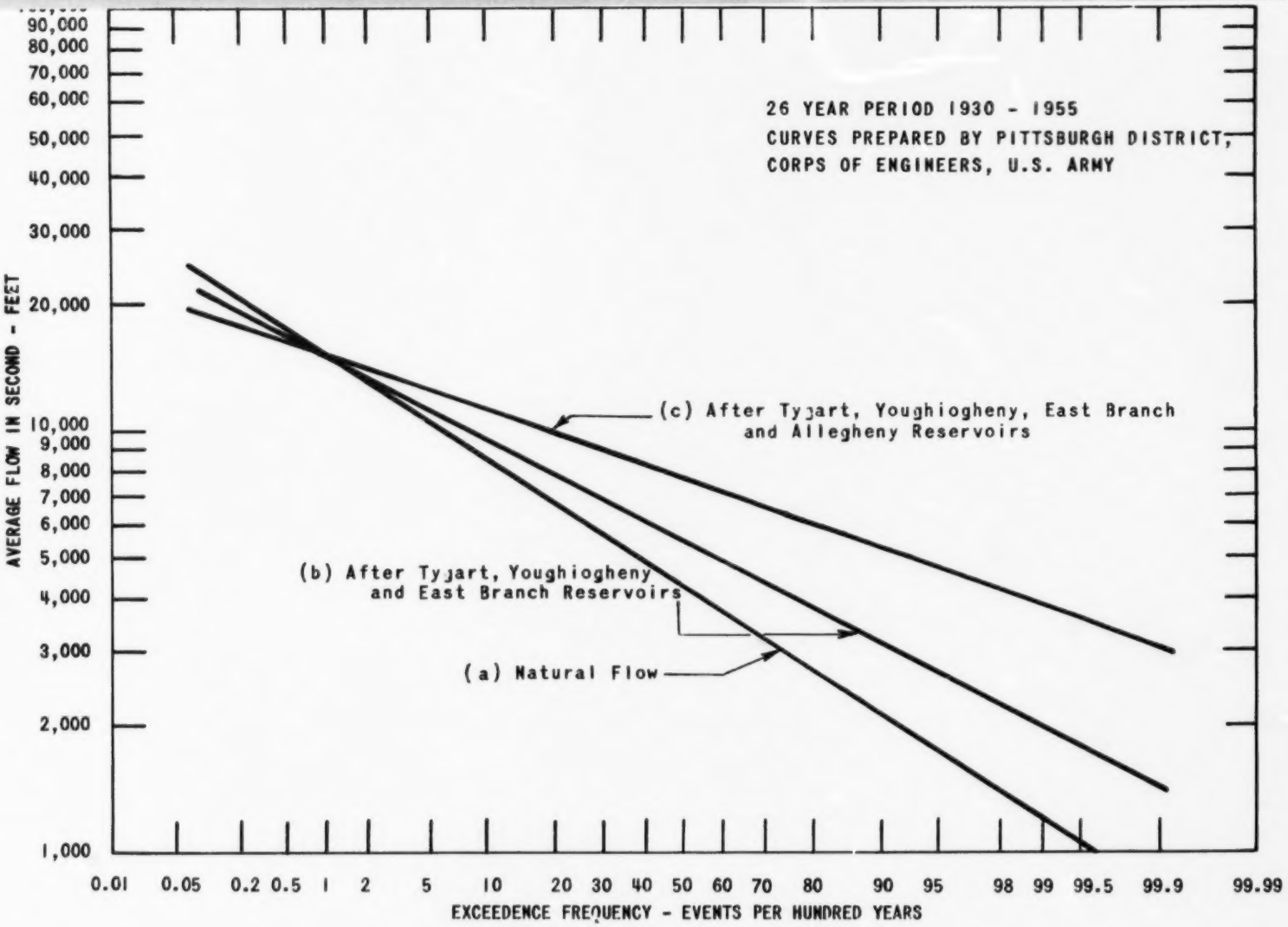
ALLEGHENY RIVER AT NATRONA, PA., LOW FLOW FREQUENCY
MONTHLY MEAN LOW FLOW

FIGURE 8



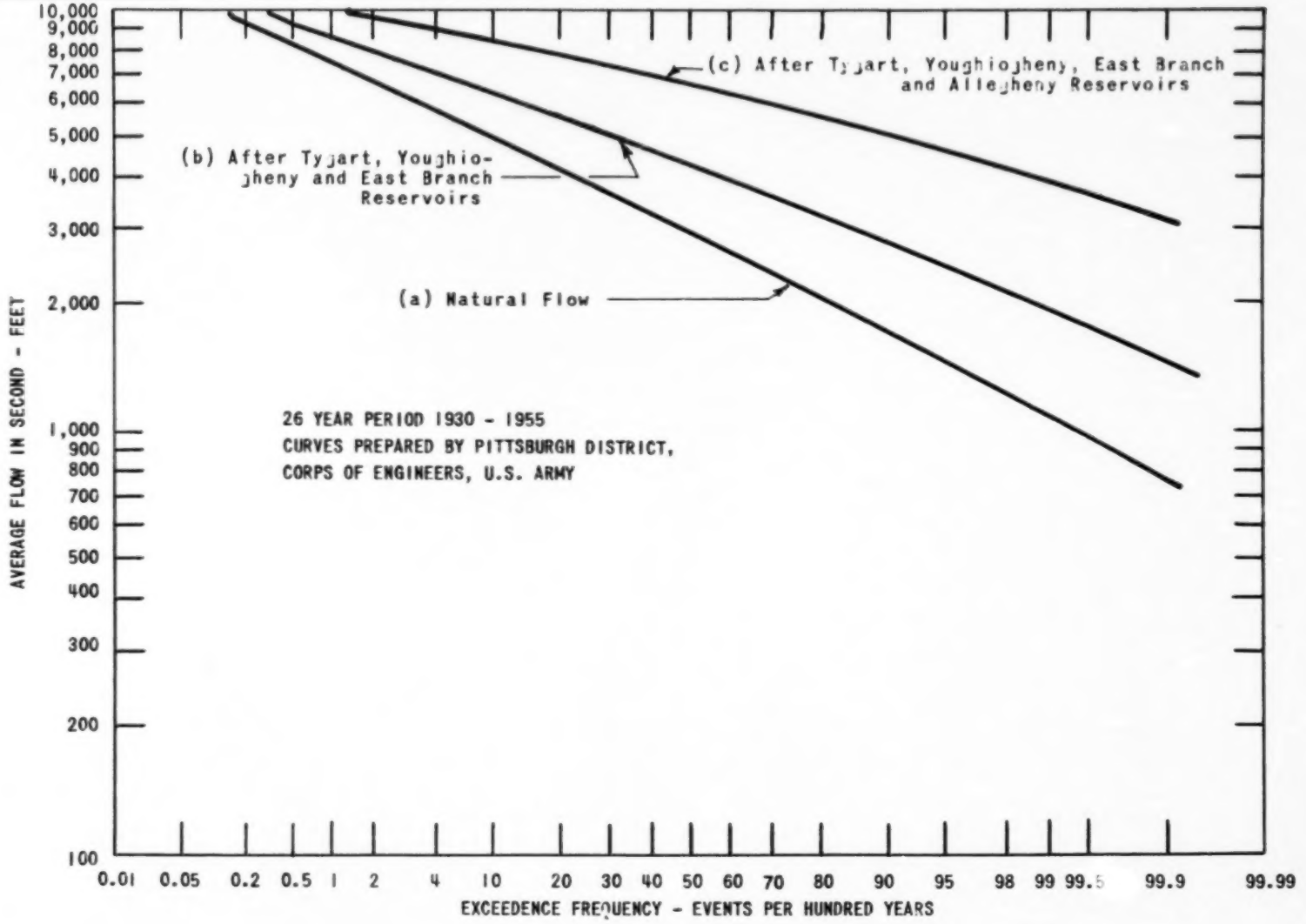
ALLEGHENY RIVER AT NATRONA, PA., LOW FLOW FREQUENCY
SEVEN DAY MEAN LOW FLOW

FIGURE 9



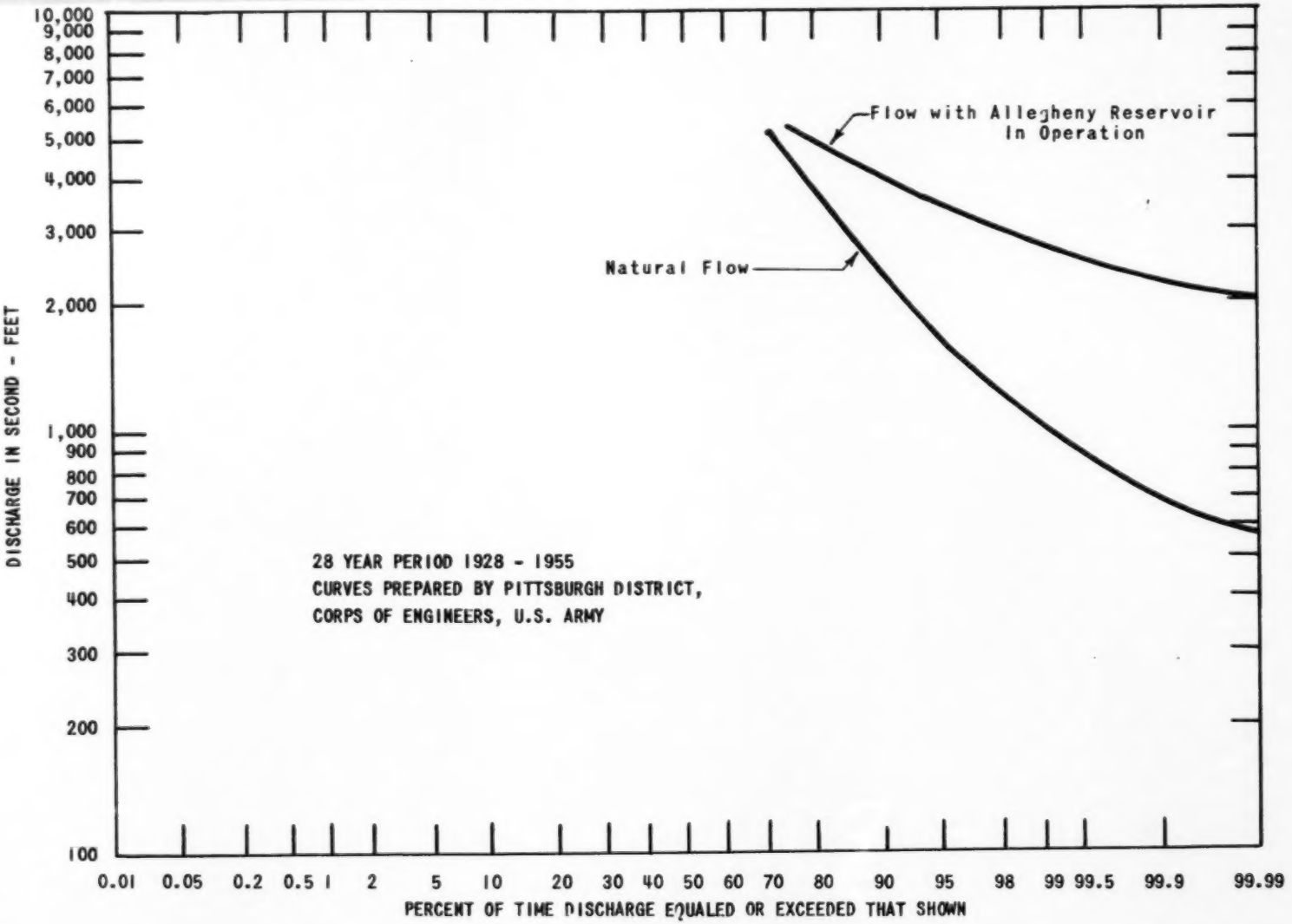
OHIO RIVER AT SEWICKLEY, PA., LOW FLOW FREQUENCY
MONTHLY MEAN LOW FLOW

FIGURE 10



OHIO RIVER AT SEWICKLEY, PA., LOW FLOW FREQUENCY
SEVEN DAY MEAN LOW FLOW

FIGURE 11



ALLEGHENY RIVER AT NATRONA, PA., FLOW DURATION CURVE

FIGURE 12